Improving Week 3-4 Weather Prediction Through a Global Convection-Allowing Version of the NOAA Unified Coupled Modeling Framework

Briefing to NGGPS

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Project Overview

- Test potential for improving sub-seasonal to seasonal (S2S) forecasts through **enhancing the resolution of the global atmospheric component** in UFS to convection-allowing scale.
- **Increasing the spatial resolution** of global climate models demonstrably enhances S2S prediction skill
- However, there are limits.
  - Deficiencies in **sub-grid scale parameterizations may mask the benefits** of increased resolution.
  - Major drivers of S2S weather variability depend on the **organization, extent, intensity and frequency of deep convection**, especially in the tropics
- Hypothesis: **Poorly resolved cumulus convection can degrade global forecasts at all lead times**.
- Hypothesis test: a series of sub-seasonal ensemble re-forecast experiments employing 3 different configurations of a global model:
  1. **Global "NWP" resolution (C768 – 13 km)**
  2. **Global "convection allowing" model (CAM) resolution (C3072 – 3.5 km)**
  3. **"Nested/stretched grid" resolution to capture tropical convection** (suggested by Weber and Mass, 2019)
     - CAM grid (3.5 km) in the tropics
     - NWP grid (13 km) outside the tropics

Project Overview

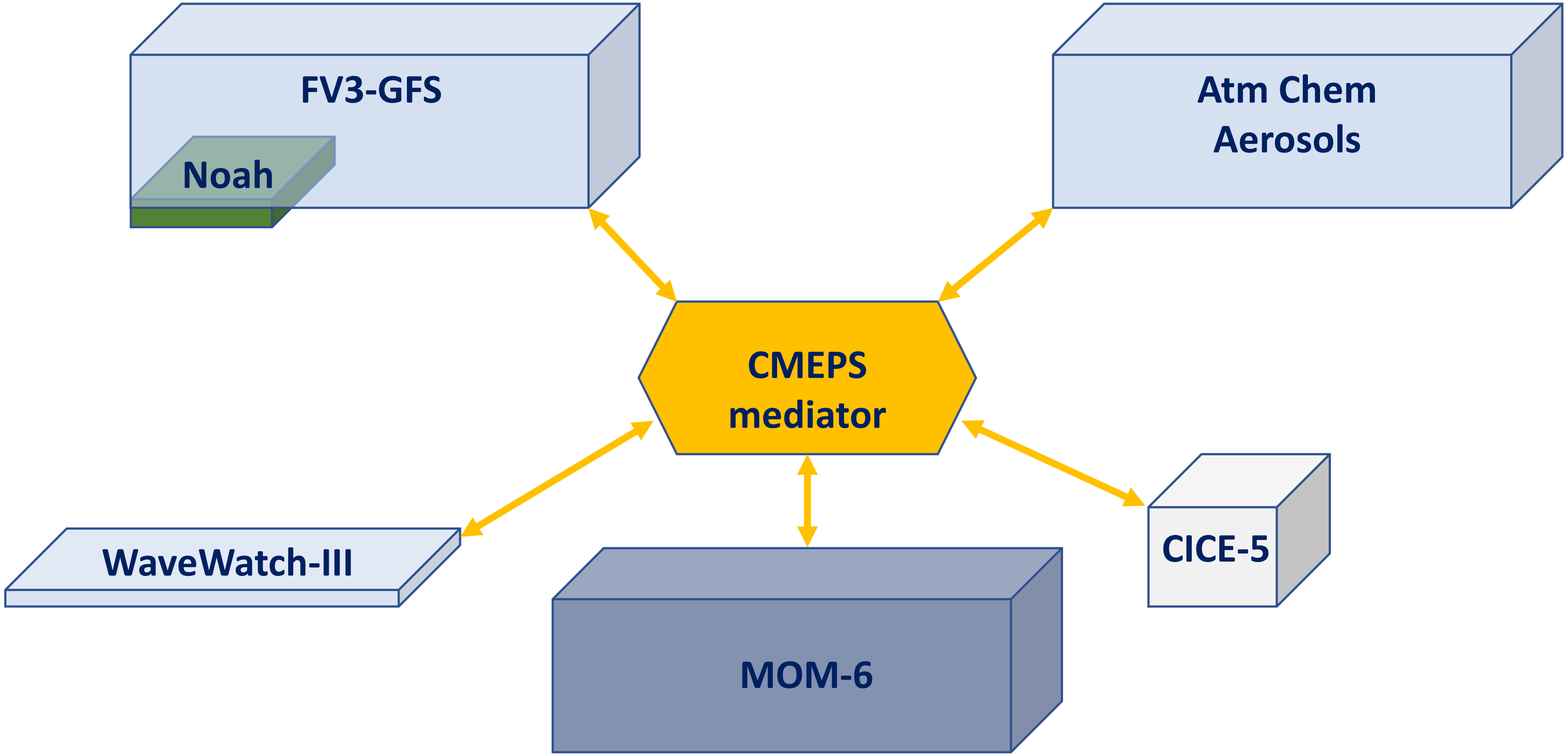
- Requirements
  - **Atmospheric initial conditions** at C768 and C3072, e.g., from reanalyses*
  - **Oceanic initial conditions** at 0.25° *
  - **Land surface initial conditions**
  - **Sea ice initial conditions**
  - UFS (FV3-GFS + MOM6 + Sea Ice Model) **running at C768/0.25° and C3072/0.25°**
  - **Post-processing (workflow)**
  - All codes and workflows to be made available to **UFS community via github**
- Evaluation: Differences in **weeks 3-4 forecast skill for precip and T_{2m}** in the contiguous United States, including the potential for outlooks of extremes
  - Local contributions from explicit representation of cumulus vs. teleconnections

* No data assimilation cycling

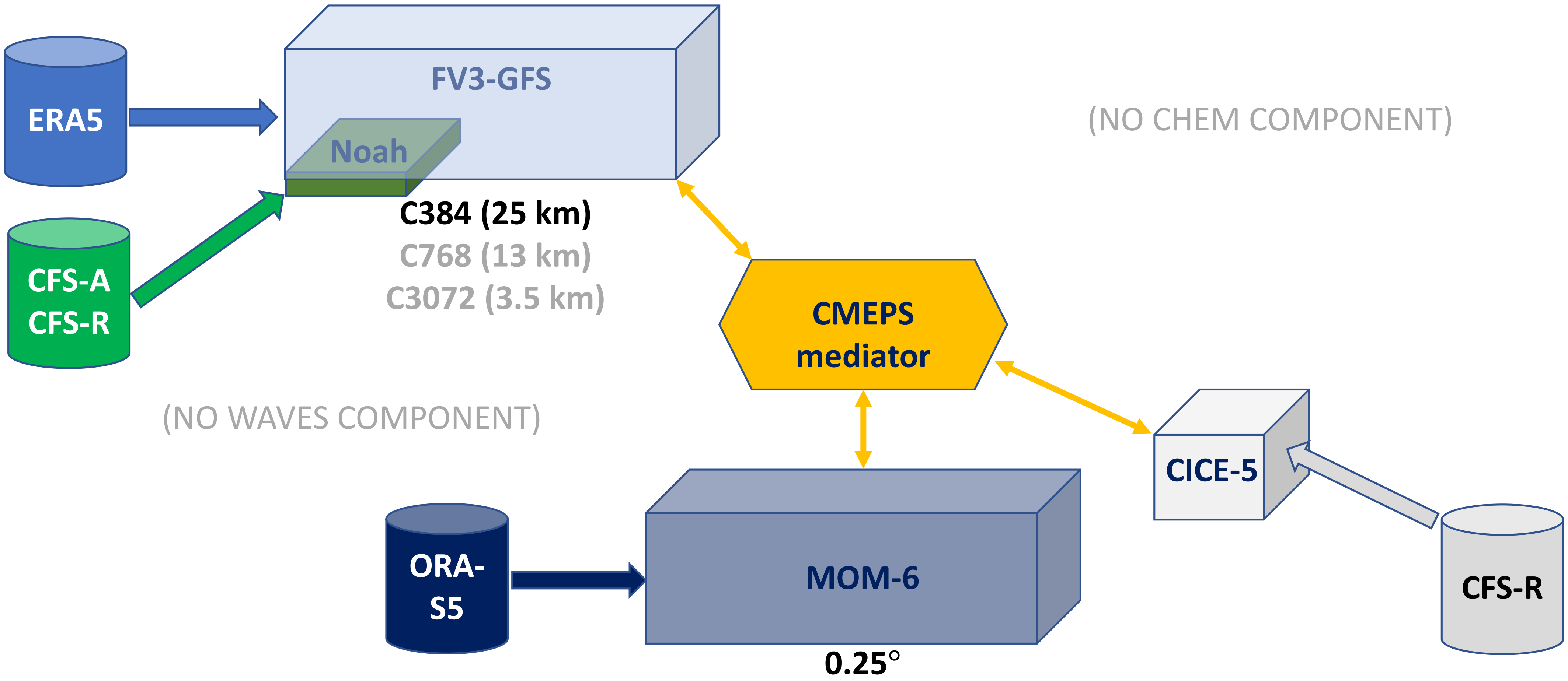
Project Overview

- Progress
  - **Ported UFS to Stampede2**
    - Collaboration with NCAR (many thanks to Rocky Dunlap, Ufuk Turuncoglu, Mariana Vertenstein)
    - Able to run UFS 4-component system with CMEPS Mediator (see next slide) at Cheyenne (NCAR) and Stampede-2 (TACC/XSEDE)
    - MET/METPlus also ported to Stampede-2 (thanks to Julie Prestopnik)
  - **Obtained XSEDE computing resources** for phase I ("NWP" reforecasts)
    - 516K node-hours (24.7 million core-hours)
  - Developed **python-based workflow modules** to **ingest atmospheric ICs, oceanic ICs** from outside sources
    - CFS-A (2011-present) or CFS-R, via *chgres*, for atmosphere, land surface, ocean, sea ice
    - ERA-5 for atmosphere (land – later)
    - ORA-S5 for ocean (sea ice – later)
  - Developed **python-based workflow modules** to **post-process atmosphere, ocean forecast output**

Model Configuration

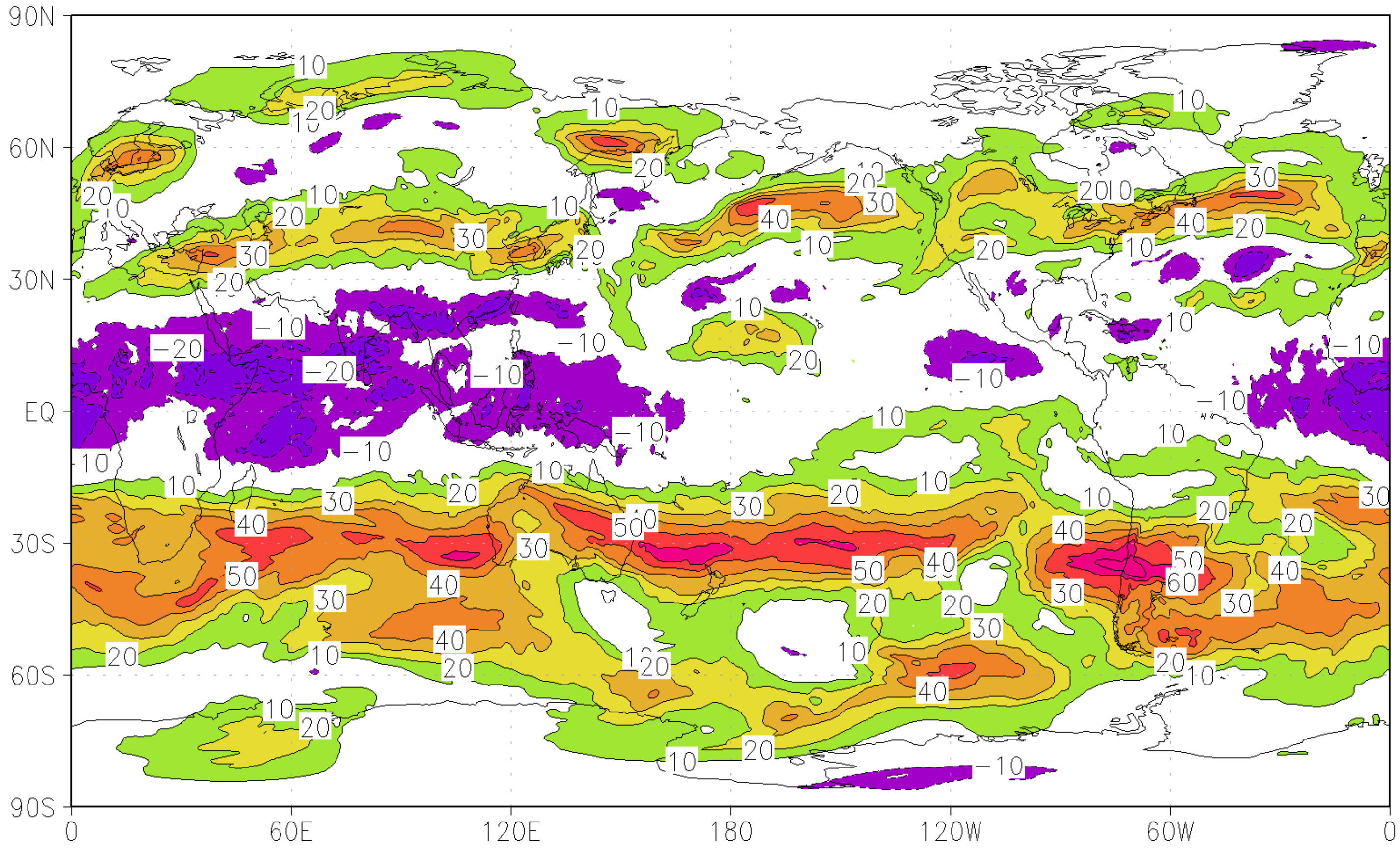


Model Configuration – This Project



Example: ICs from CFS-A

UFS U wind at 200 hPa
00Z01Jul2012 (CFS-A)



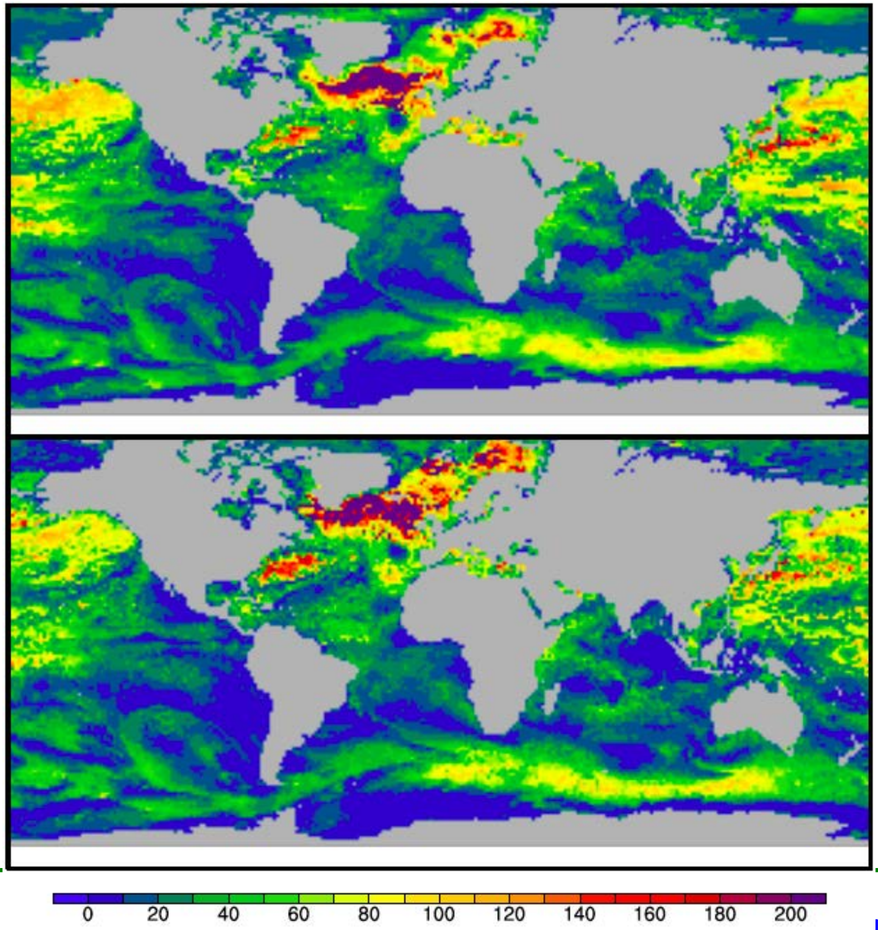
5-day run of UFS CMEPS0.5 initialized by ORA-S5 Temperature and Salinity (IC: 00Z 01 January 2012)

CTRL: Default ICs based on NCEP CFS analyses (*ocean T and S IC: 1°x1° regular lat/lon grid with 40 vertical levels)

EXP: Same as CTRL but ECMWF ORA-S5 T and S IC (0.25°x0.25° regular lat/lon grid with 74 vertical levels)

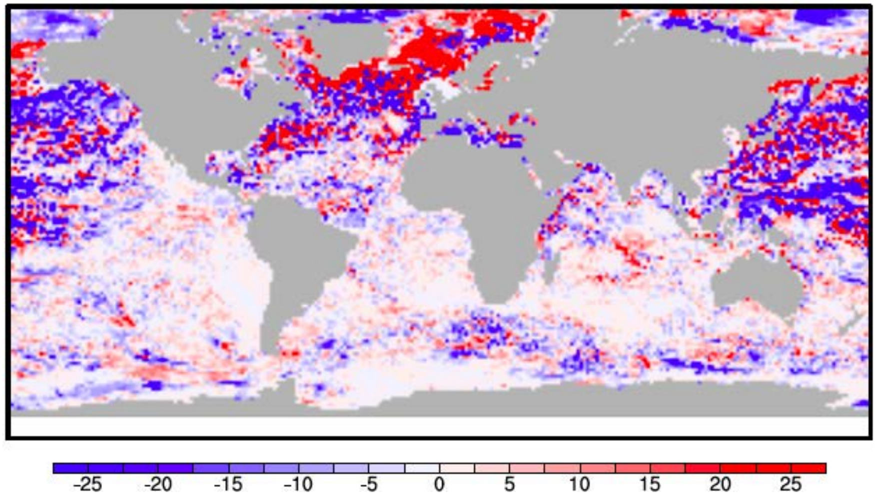
CTRL

EXP



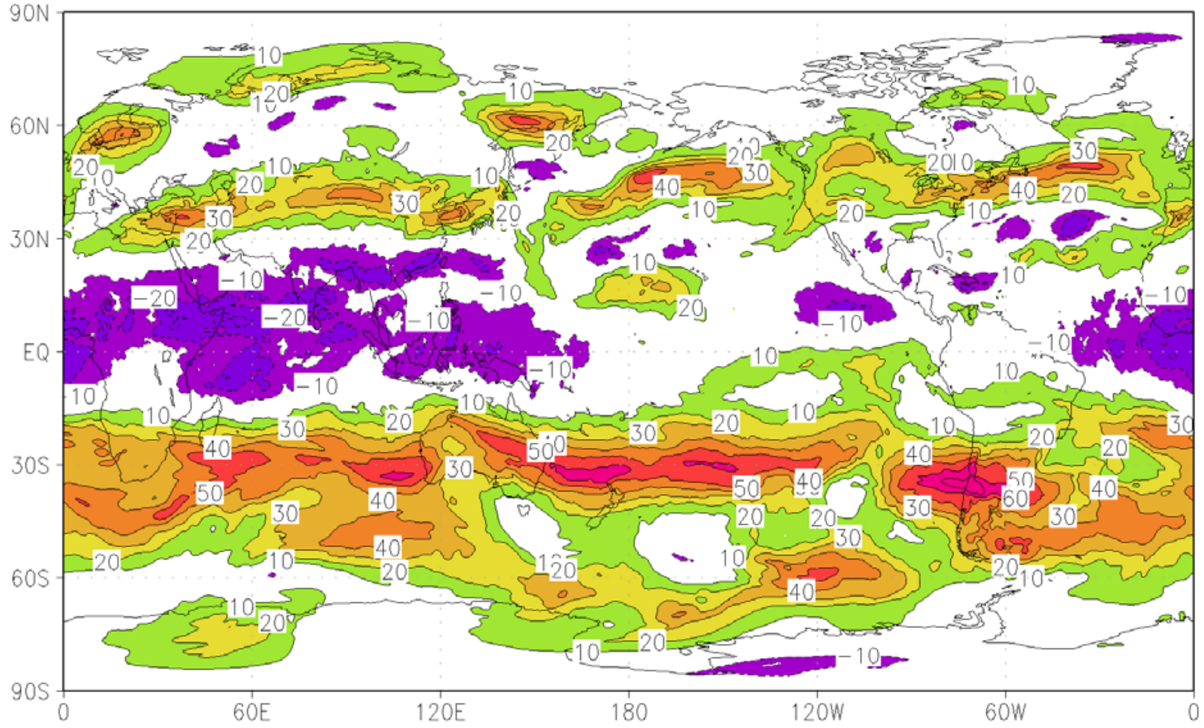
Surface Boundary Layer Depth (m) at day 5
(6-hourly mean for 18z-00z at day5)

EXP minus CTRL

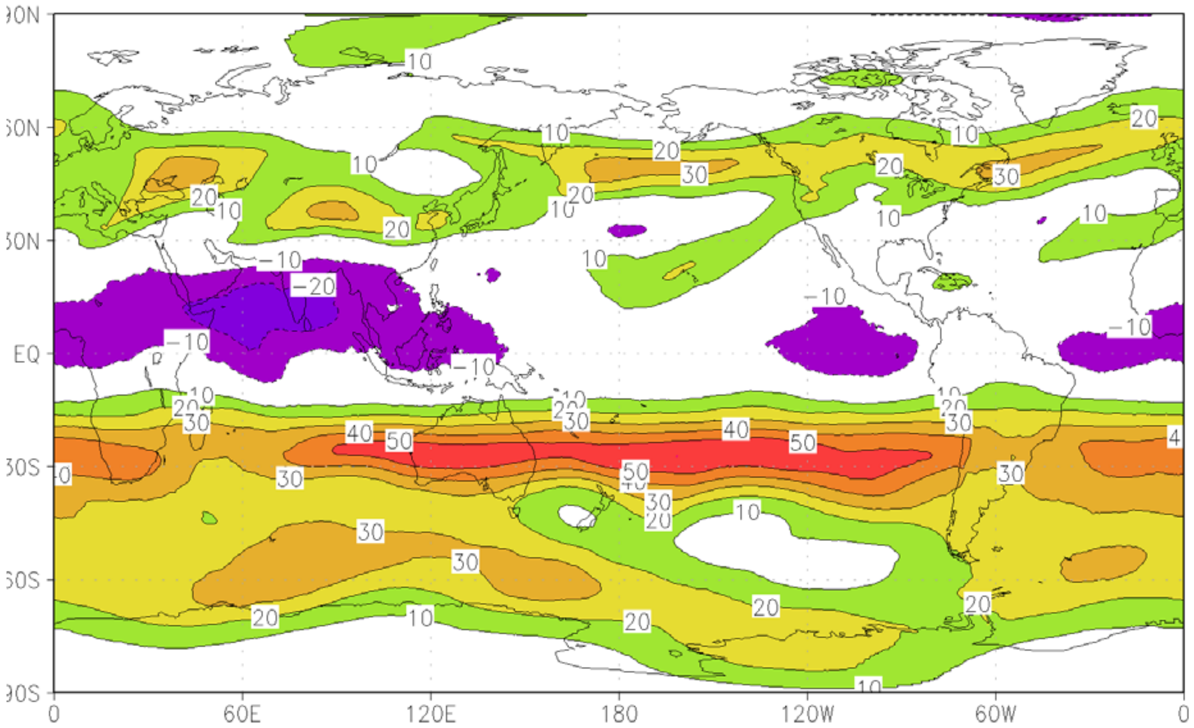


Sample Run C384 / 0.25°

UFS U wind at 200 hPa Initial Condition 00Z01Jul2012 (CFS-A)

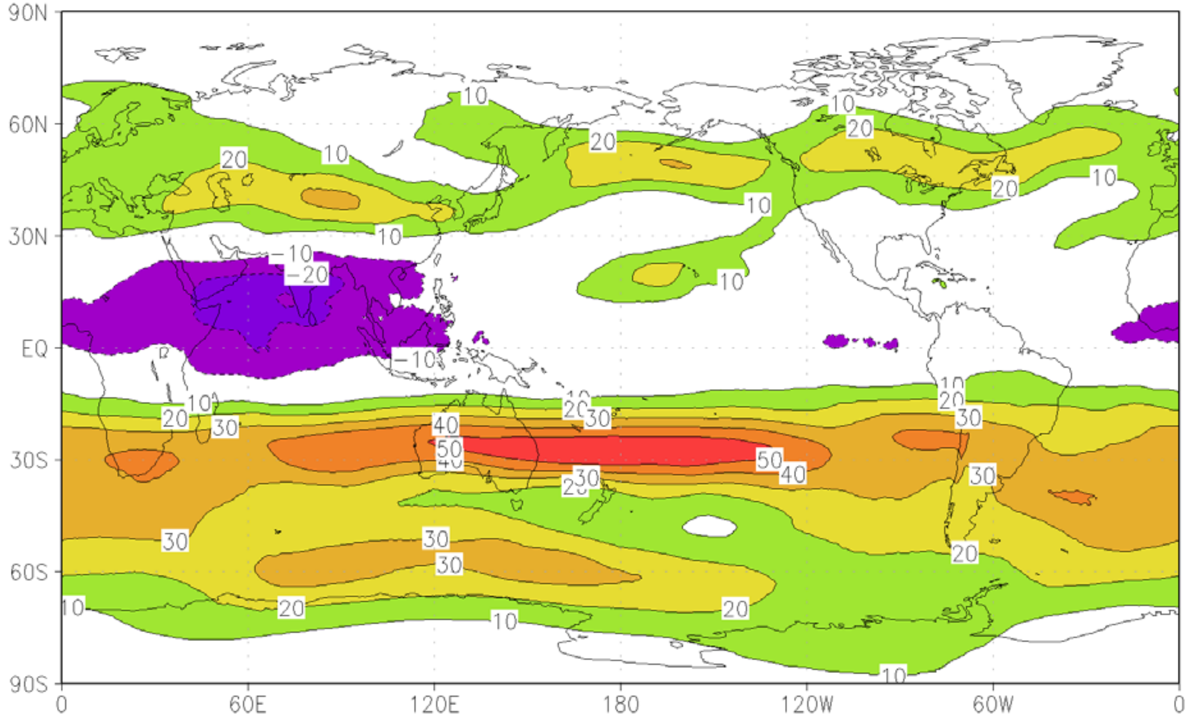


UFS U wind at 200 hPa Weeks 3-4 Mean 00Z07Jul2012 – 18Z29Jul2012

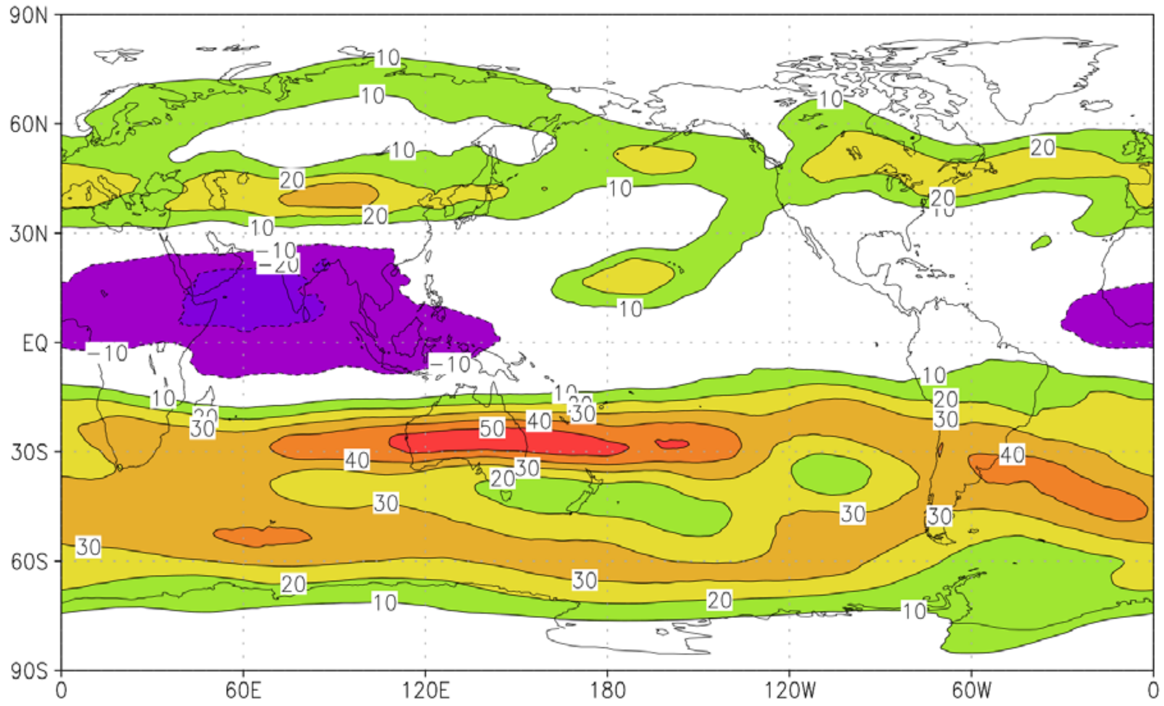


Sample Run C384 / 0.25°

UFS U wind at 200 hPa 01-31 July mean
ICs: 01Jul2012 (CFS-A)



UFS U wind at 200 hPa 01-31 July mean
Verification (CFS-A)

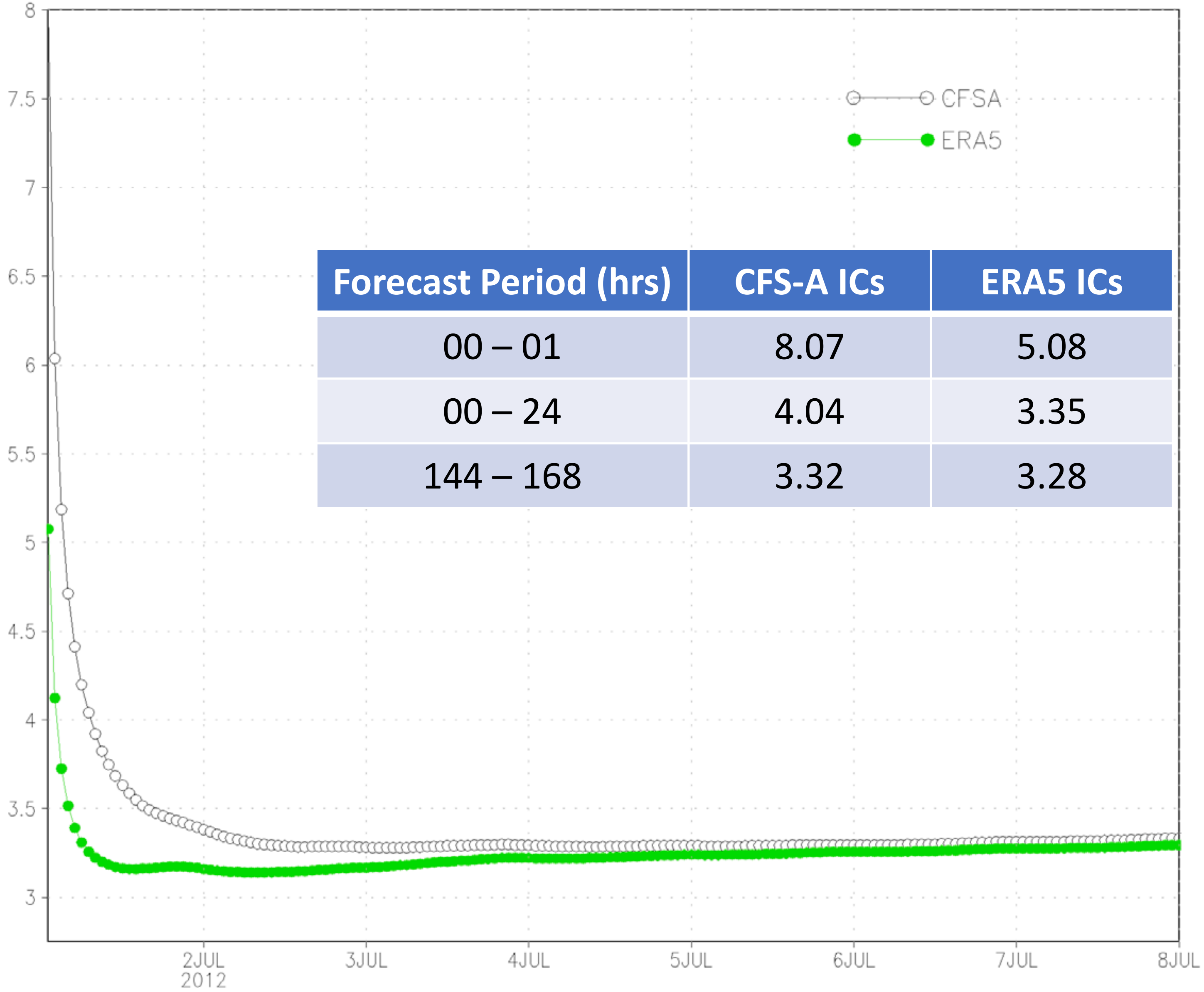


Water Cycle Spinup

C384 / 0.25°
FV3GFS / MOM6-CICE5
01 July 2012 ICs

ERA5 Atmos ICs vs. CFS-R Atmos ICs
CFS-A Ocean and Sea Ice ICs

Global Mean Hourly Precip Rate (mm/day)

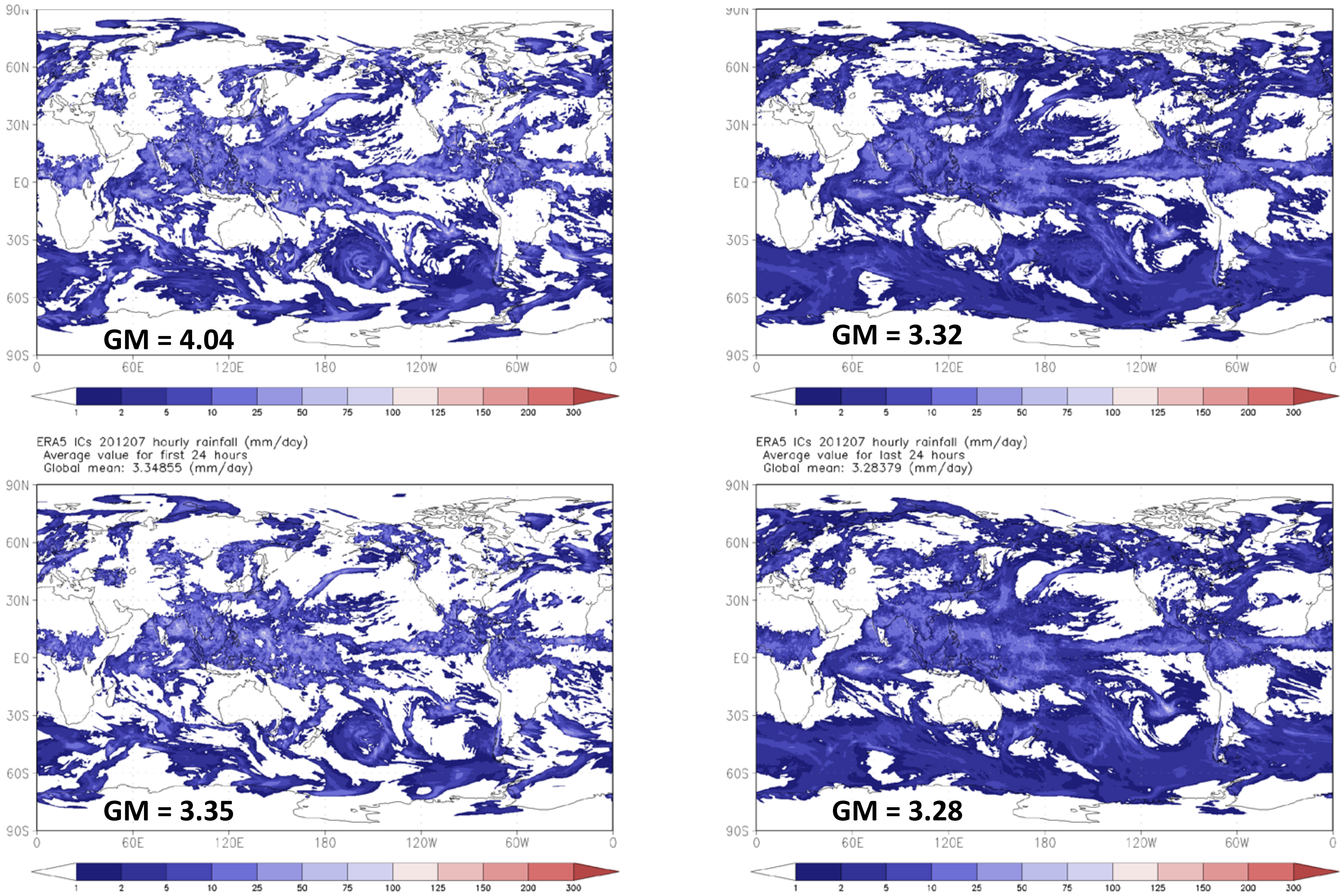


Forecast Period (hrs)	CFS-A ICs	ERA5 ICs
00 – 01	8.07	5.08
00 – 24	4.04	3.35
144 – 168	3.32	3.28

Precip Rate (mm/d) Hrs 0 - 24 | Precip Rate (mm/d) Hrs 144 - 168

CFS-A Atmos ICs

ERA5 Atmos ICs



C384 / 0.25°
FV3GFS / MOM6-CICE5
01 July 2012 ICs

CFS-A Ocean and Sea Ice ICs

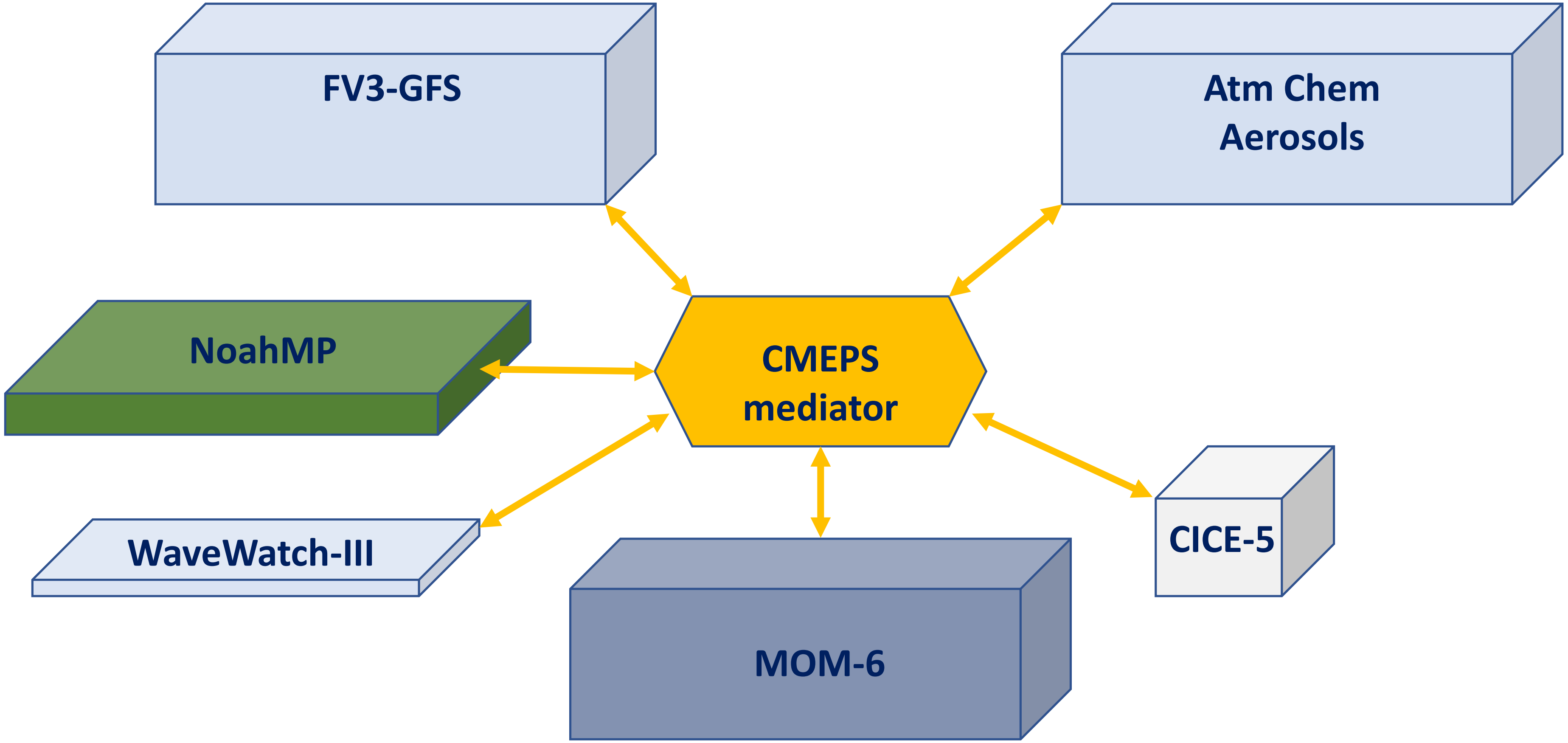
Next Steps

- Configure model for ”NWP” resolution (C768/0.25°)
  - Exchange grid, land-sea mask, other fixed fields
  - Initial conditions from ERA-5
- Initialize land surface from external source (see next slide)
- Initialize sea ice from external source (e.g. ORA-S5)
- Configure model for ”CAM” resolution (C3072/0.25°)
  - Collaboration with Lucas Harris (GFDL)
- Obtain computing resources for CAM runs

Land-Atmosphere

- Goal: Incorporate in UFS a unified Noah-MP+WRF-Hydro model in fully coupled Earth system model (ESM) with application to global Weather and S2S prediction
- Requirements:
  - Unify terrestrial land and hydrology physics for multiple scales under UFS, prioritizing proper representation of important coupled processes.
  - Ensure scaling consistency between land-hydrology (~1km) and UFS atmosphere grid (global NWP and S2S; ~10km) to properly represent land-hydrology-atmosphere exchanges.
  - Focus on Weather to Subseasonal applications:
    - Land states and fluxes have the greatest impact on prediction at diurnal to subseasonal time scales
    - Improvements in LS (initialization and physics) will improve simulation of land states and fluxes
    - Therefore, more realistic land-hydrology modeling in UFS will improve NWP to S2S prediction, particularly for surface variables such as temperature and precipitation.
- Short-term: Couple the Noah-MP model as a separate component in UFS
- Long-term: Consider unifying Noah-MP, WRF-Hydro and CLM (plant phenology, carbon cycle, soil thermodynamics, land cover tiling, etc.)

Model Configuration – Near-Term



Model Configuration – Long-Term